Single Event Response of Embedded Power PCs in a Xilinx Virtex- 4 FPGA for a Space Application

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Outline

- **Introduction**
- **Test Set-up and Conditions**
- **Destructive Heavy-ion Test**
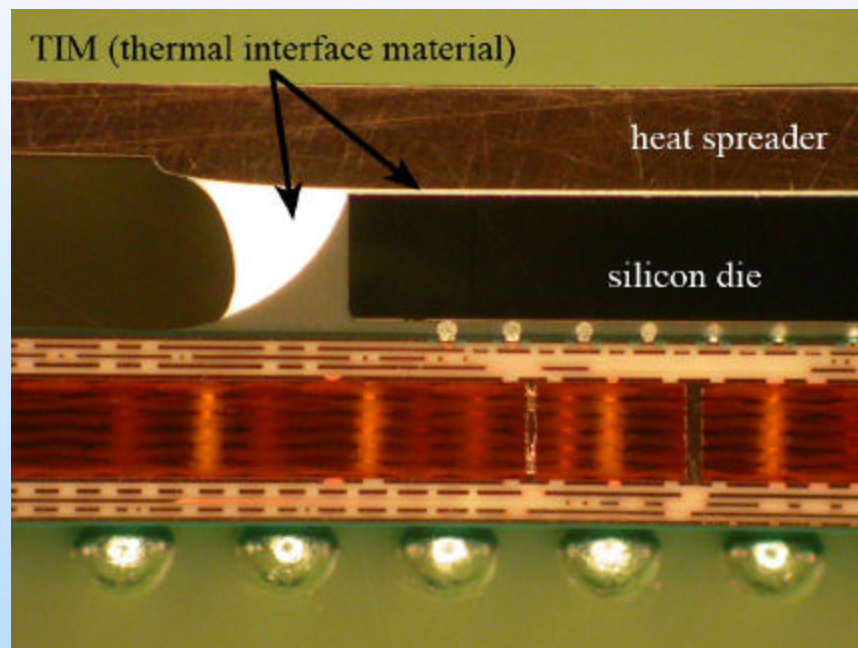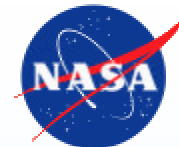- **Heavy-ion SEE Test**
- **Proton SEE Test**

Presented by Christian Poivey at the 2007 Single Event Effects Symposium (SEESYM), April 10, 2007 to April 12, 2007 in Long Beach, CA.

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Introduction-Background

- **Mission**
  - **Express Logistic Carrier (ELC)**
  - **International Space Station (ISS) radiation environment**
    - **Moderate SEE requirements**
    - **Moderate TID requirements**
- **Application**
  - **Embedded computer (Space cube)**
  - **Uses two XC4VFX60 FPGAs: four Power PC processors**
    - **Each processor is allocated 50% of FPGA fabric and is considered as an independent node.**
  - **Four processors run independently of each other, and results are voted on in a separate radiation hardened (RH) FPGA.**
    - **RH FPGA traps error condition and flags faulty processor node**
    - **RH FPGA restores PPC functionality (warm reset, full reboot, reconfiguration,…)**
  - **No mitigation in FPGA design except scrubbing of configuration memory to keep processors running as long as possible**
    - **External scrub**
    - **Self scrub using FPGA Internal Configuration Access Port (ICAP)**

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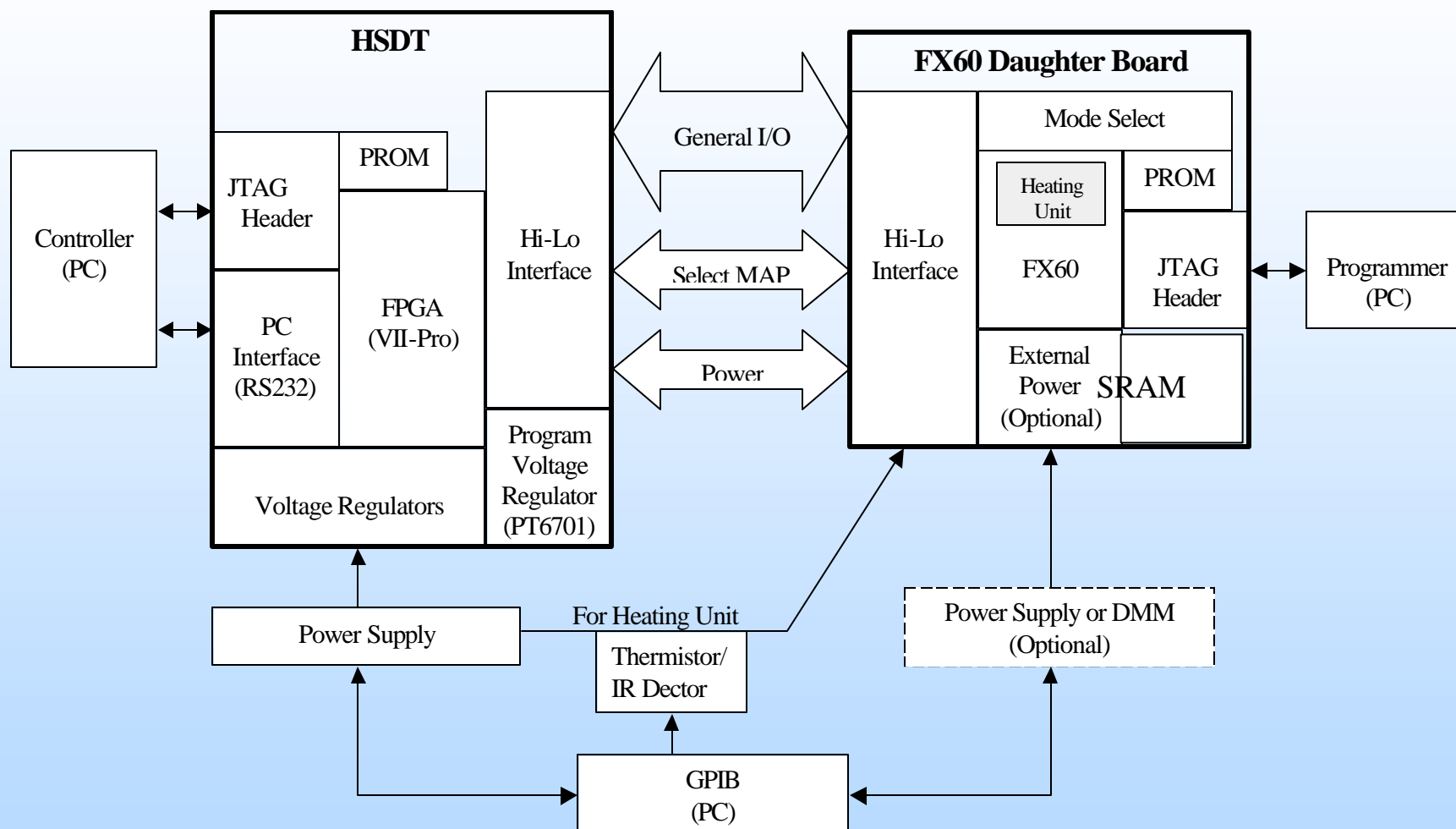
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Introduction – Test Approach

- **Device**
  - **XC4VFX60 FPGA**
    - **Virtex-4, embeds two power PC405 cores**
    - **90 nm CMOS bulk commercial process**
    - **Some radiation data available on Virtex-4, but not on versions with PC core.**
- **Test approach**
  - **Destructive test (go no go)**
    - **No die thinning**
  - **SEE Tests**
    - **Die thinning (100 μm)**
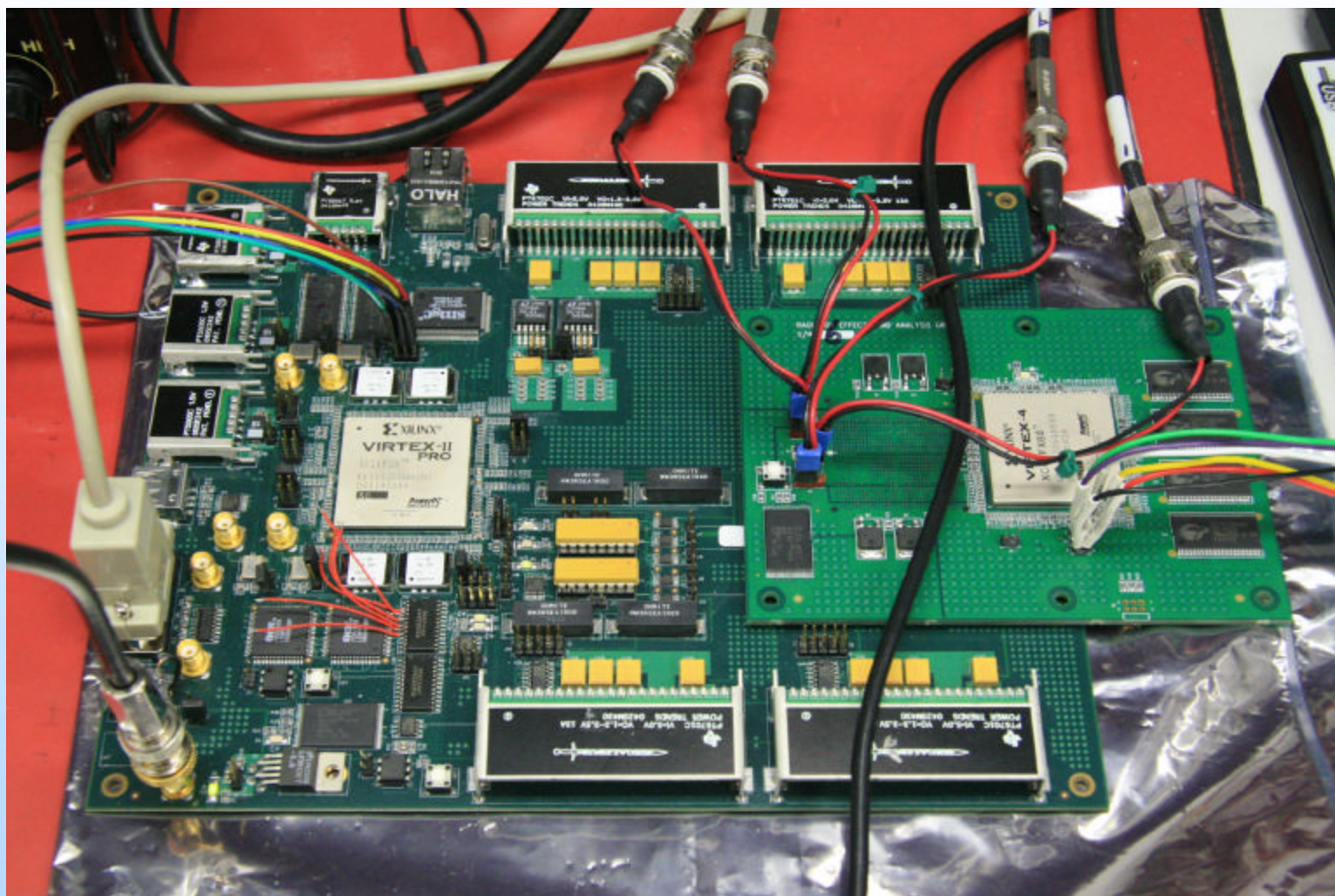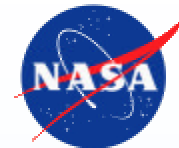   - **Heavy-ion and protons**
  - **TID tests**

TIM (thermal interface material)

heat spreader

silicon die

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Test Set-up

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Test Set-up

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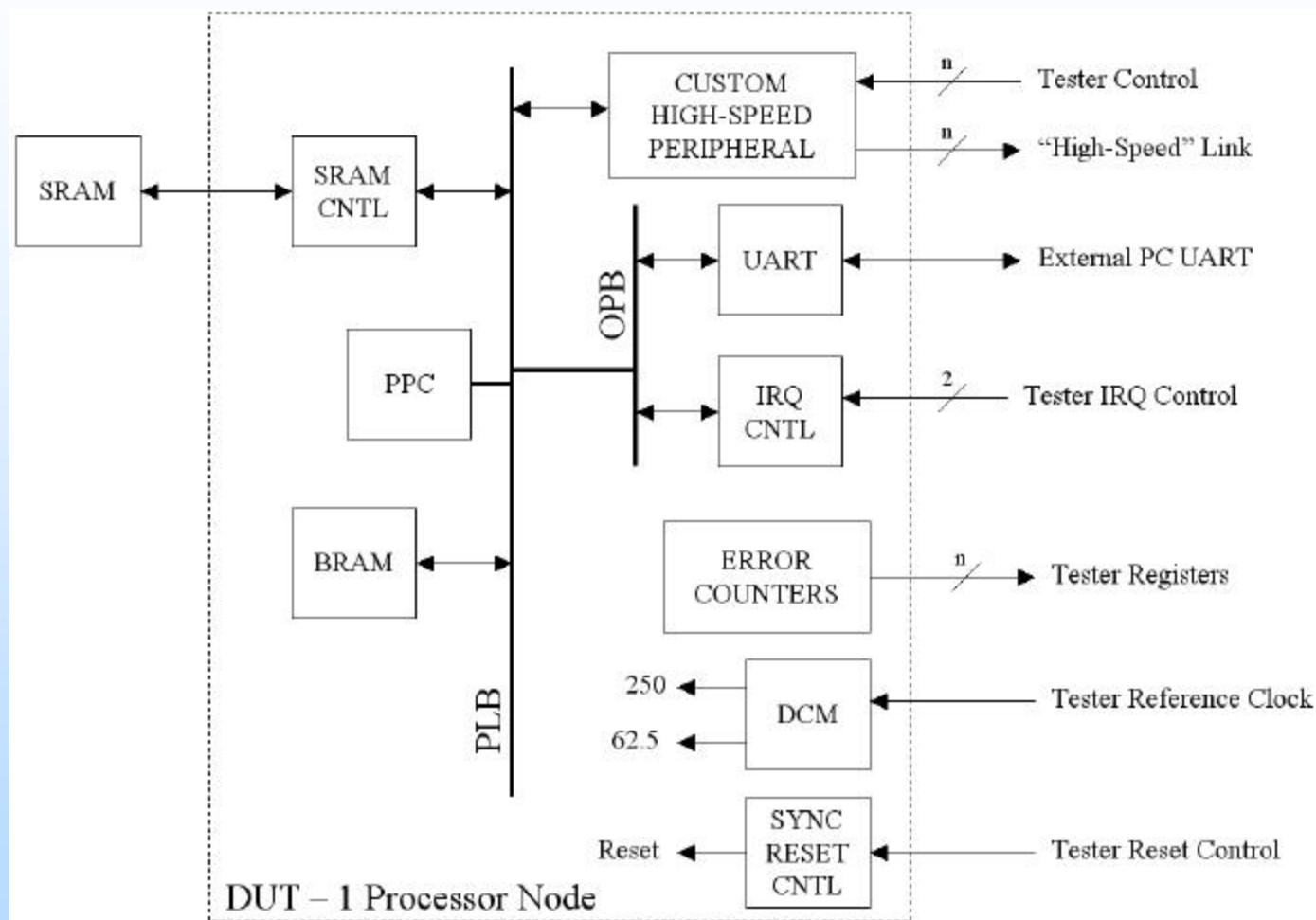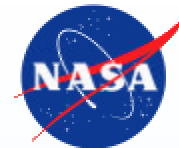
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DUT Design

+ shift registers

2 versions of DUT design: with and without self-scrubbing

Test Conditions

- **Destructive Test**
  - **Test samples from Xilinx**
  - **Unshaved dice**
  - **DUT design without high-speed link**
  - **No implemention with self-scrubbing**
  - **External scrubbing at 32 MHz**
  - **PPC test program running from BRAM**
  - **Multi-interrupt test program sending interrupt requests to each PPC every second**
  - **No readback of configuration memory after each run**
  - **Heavy-ion test at MSU with 106 MeV/u Xe beam**
  - **Tests at 80°C die temperature**

- **Full SEE tests**
  - **Test samples from flight lot**
  - **Shaved dice (100 mm) for heavy-ion test**
  - **DUT design with high-speed link**
  - **One implementation with self scrubbing**
  - **External scrubbing at 32 MHz**
  - **PPC test programs running from external SRAM**
  - **Multi-interrupt test program sending interrupt requests to each PPC every 100 ms.**
  - **Counter program**
  - **Heavy ion test TAMU with 25 MeV/u beams**
  - **Protons tests at IUCF**
  - **Readback of configuration memory after each run**
  - **No heating (~65°C die)**

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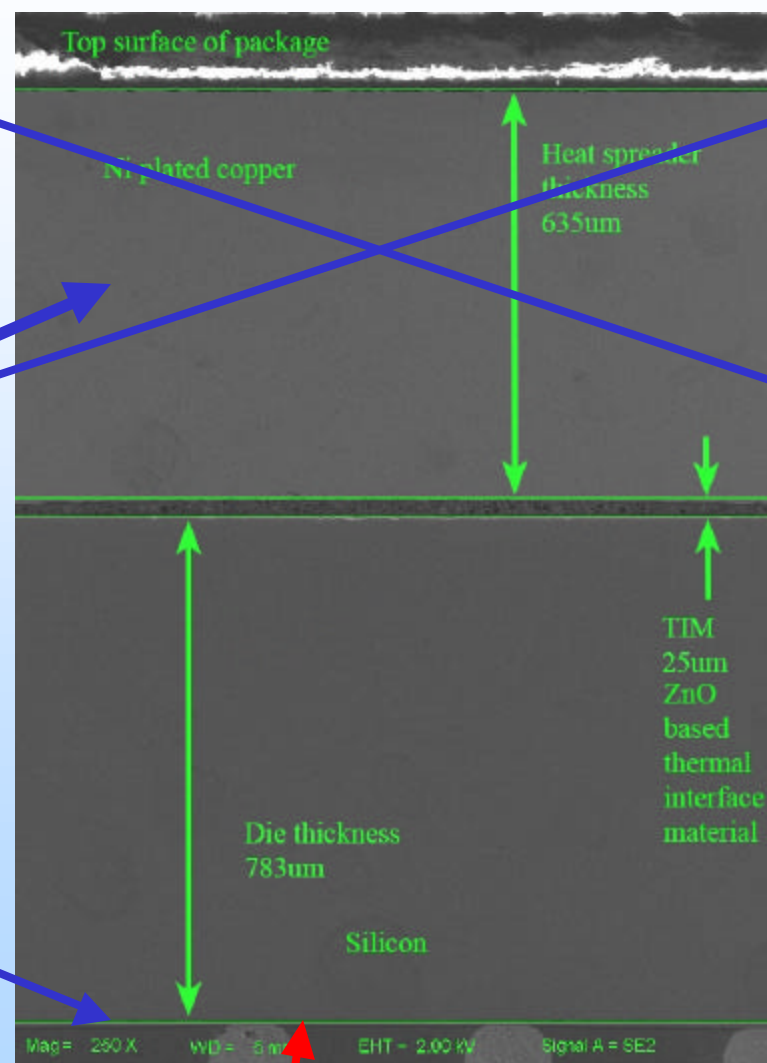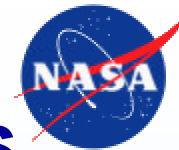
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Destructive Test

- MSU cyclotron:
  - Xe beam, 106 MeV/u (14.4 GeV) after scattering foil
  - 12" of Air between scattering foil and DUT
  - DUT delidded
  - Flux between 25 and 300 #/cm²-s

LET=19 MeVcm²/mg at normal incidence

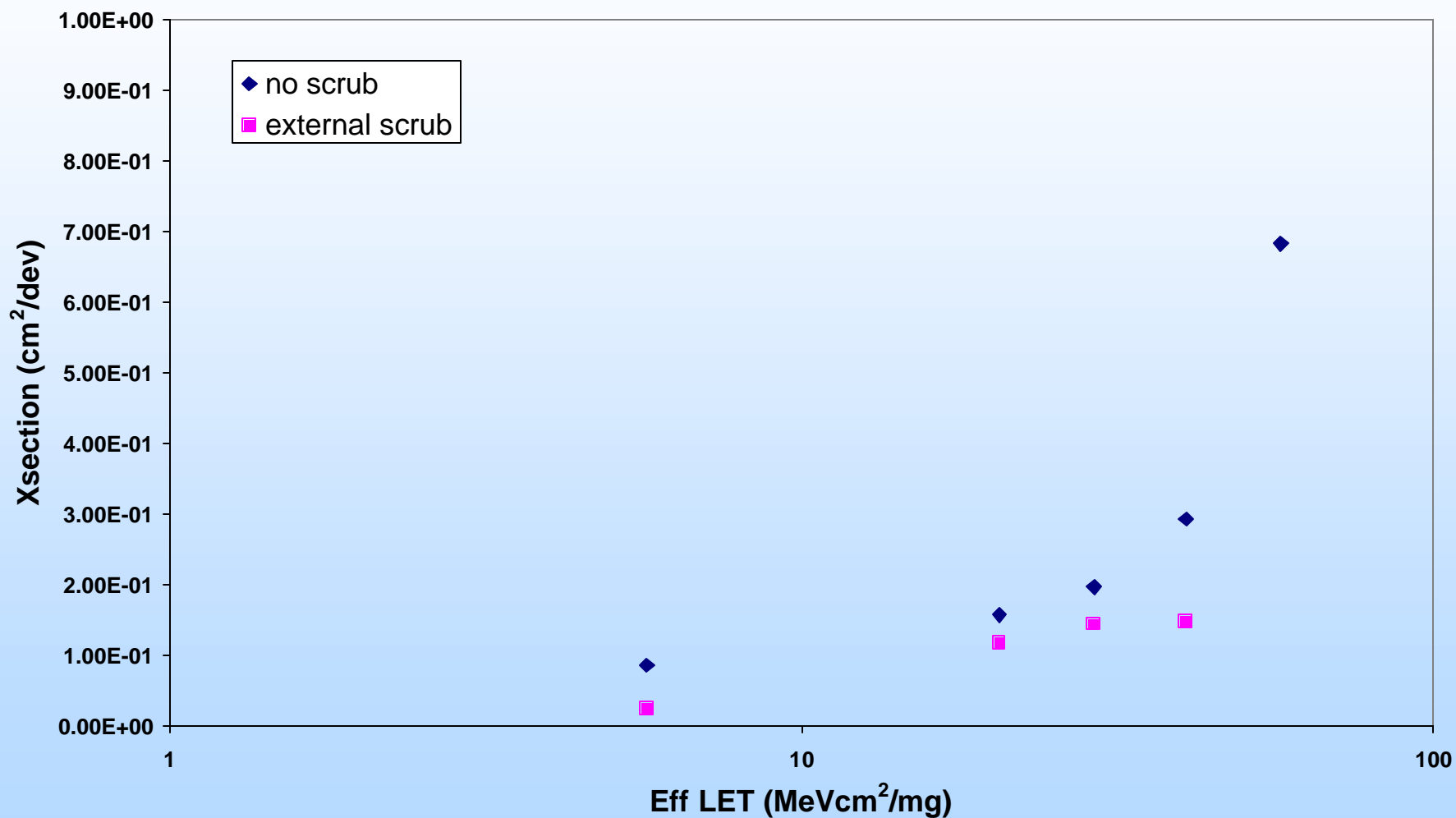**LET=30 MeVcm²/mg at 45 degrees inclination**

Top surface of package

Ni plated copper

Heat spreader thickness 635um

TIM 25um ZnO based thermal interface material

Die thickness 783um

Silicon

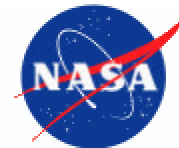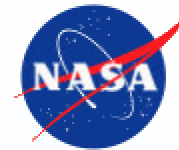Mag = 260 X   WD = 5 mm   EHT = 2.00 kV   Signal A = SE2

Active part of the die

Heavy-Ion SEE Tests, Readback Errors

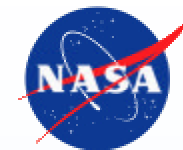Presented by Christian Poivey at the 2007 Single Event Effects Symposium (SEESYM), April 10, 2007 to April 12, 2007 in Long Beach, CA.

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Heavy-Ion SEE Tests, SEFI

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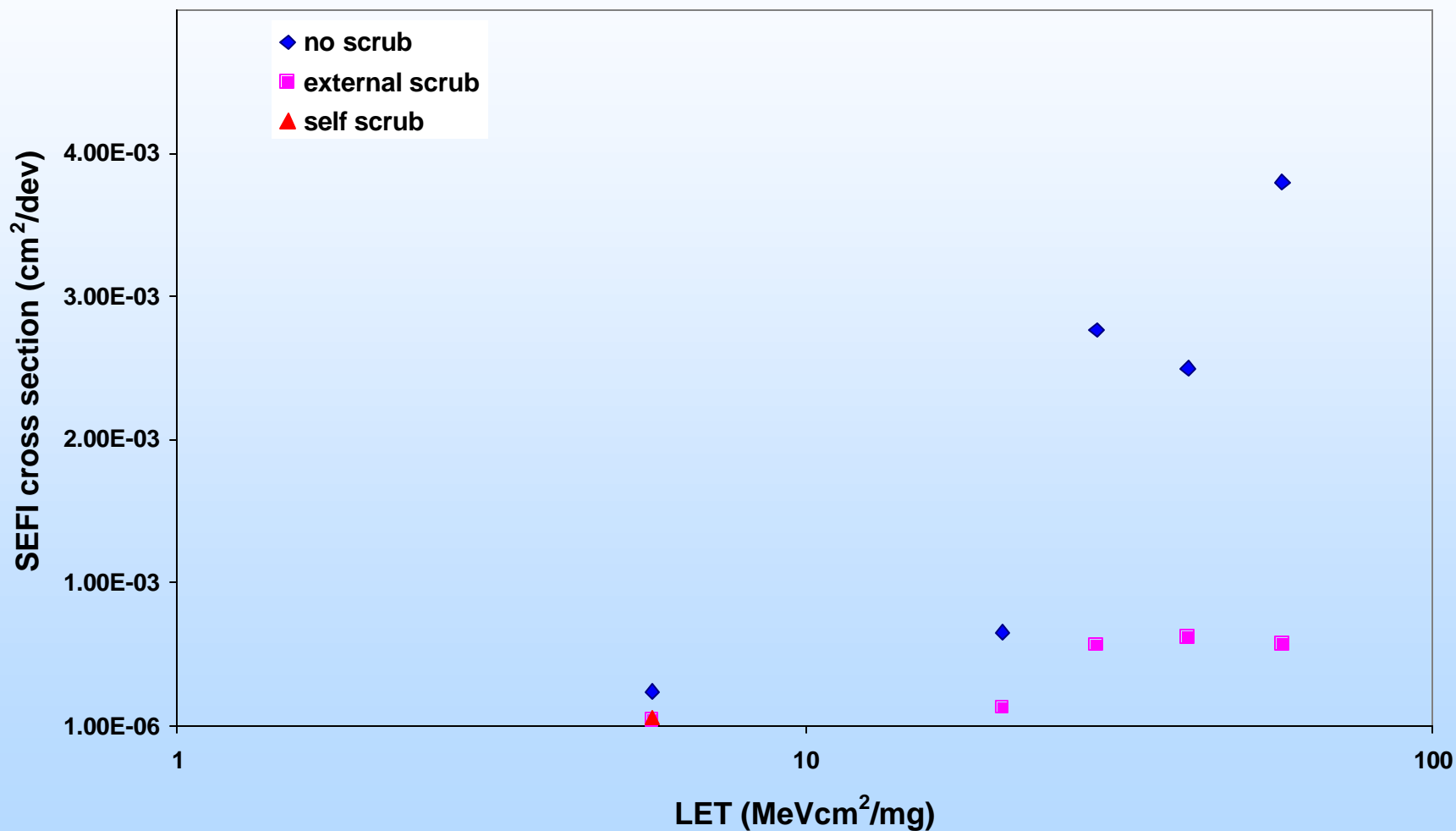
Protons SEE Tests, Readback Errors

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Proton SEE Tests, SEFI

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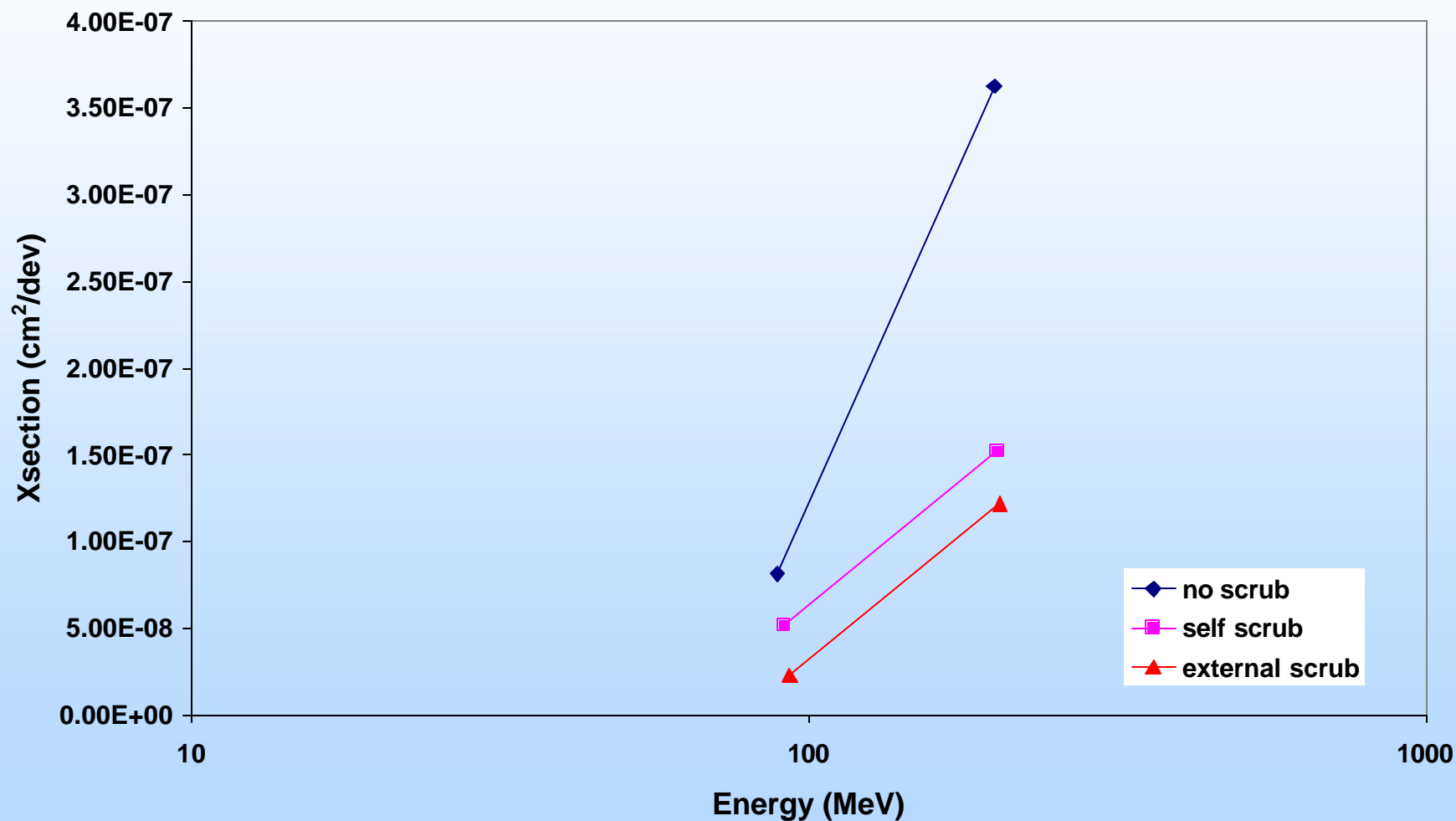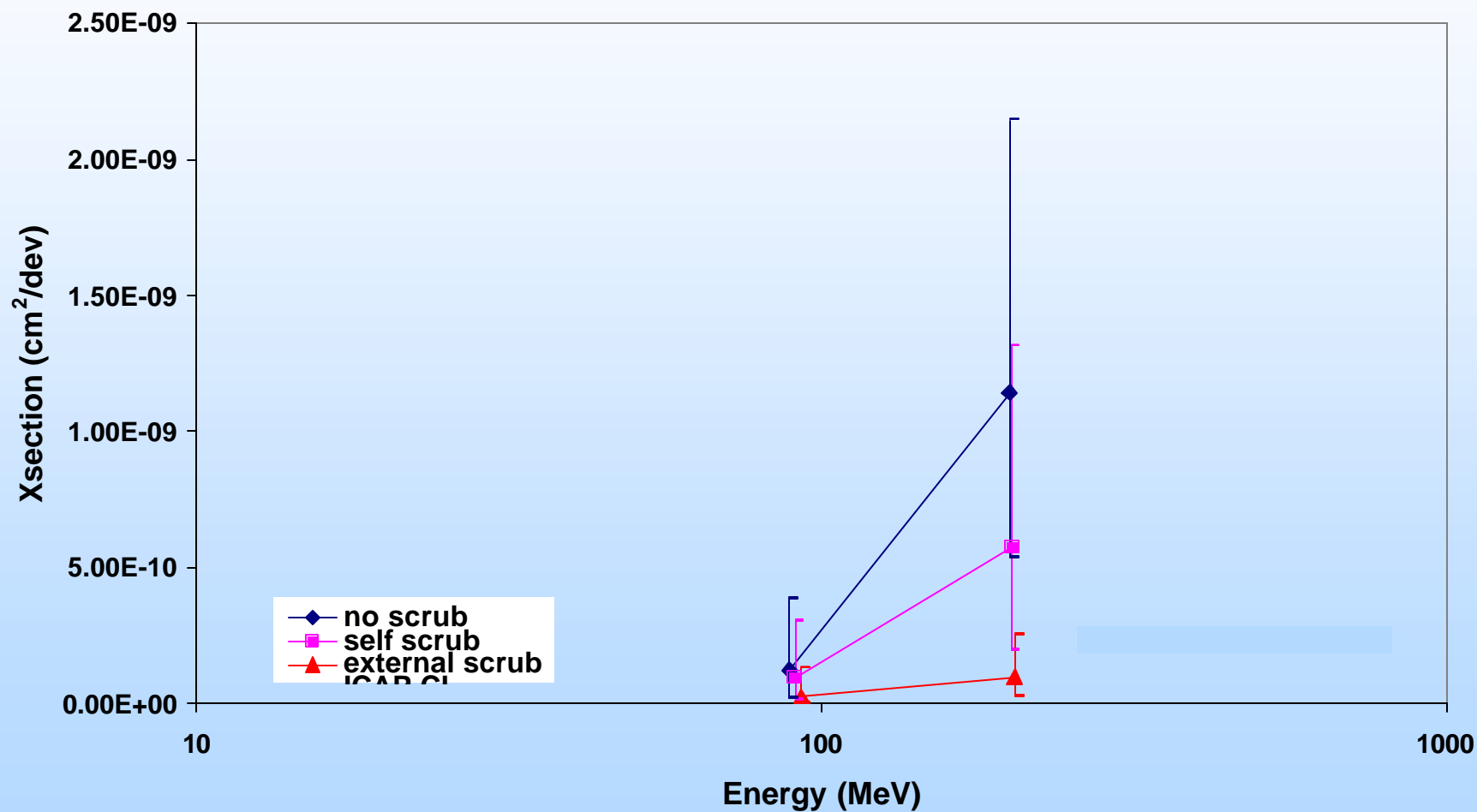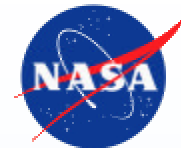
Conclusions

- **Data are still under analysis**
  - Recovery after SEFI
  - Readback files
  - Data errors

- **No destructive events up to a LET of 60 MeVcm²/mg**

- **No SEFI requires a power cycle to recover from**